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ECOLOGY SIMULATIONS-2 (Pollution, Rat Control, Malaria and Diet Simulations)

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Pollute, Rats, Malaria, and Diet...were originally developed by Dr. Ludwig Braun and others at The State University of New York at Stony Brook, as part of the Huntington Two Computer Project, partially sponsored by the National Science Foundation, Grant GW-5883. These programs were modified and graphics output added for microcomputers by Ann Corrigan of Creative Computing Software.

POLLUTE:
Water Pollution Simulation Program

I. Introduction

Many social problems today involve the management and "quality control" of natural resources. We can improve our abilities as well-informed, responsible citizens by acquiring some understanding of and insight into these ecological problems. POLLUTE capitalizes on a manageable portion of the mammoth water pollution problem. It provides a context within which you can gain some understanding of the basic scientific and economic factors involved in the water pollution problem. You can use the computer to investigate the effects of different variables such as water temperature and rate of dumping waste material. You can compare various pollution control strategies, examine possible situations without risking the impacts those situations would produce in real life; you can make and test hypotheses and can predict the implications of certain scientific and economic decisions.

II. Background

Water has always been one of our most vital and valuable resources. In addition to nourishing us, our crops and our animals, water is used in great quantities for cleansing, carrying away wastes, industrial processes, and recreation. Today, with a world population of around 4 billion, and industrial production at an all time high worldwide, the demand for water is tremendous. Each American uses an average of 70 gallons of water per day!

Despite this dependence on water, we have been carelessly polluting our water sources for many years. Today even the ocean shows signs of our pollution! Only recently have we realized that our very survival depends on our **intentional** protection of the quality of our water supplies.

One major concern in protecting water quality is to preserve the fish that inhabit the waterways. Fish breathe oxygen through their gills that has been dissolved in the water. Thus it is vital that the water contains enough oxygen for the fish to live and move easily.

As water temperature rises, fish need more oxygen, but unfortunately, the amount of oxygen absorbed into the water **decreases** at higher temperatures. To make matters worse, when some fish find they are not getting enough oxygen from the water, they will start breathing more rapidly and more deeply in an attempt to get enough oxygen. But when a fish does this, the amount of oxygen that the fish can extract from the water actually decreases! This is called "respiratory distress."

Human pollutants can affect the amount of dissolved oxygen in several ways. **Sewage**, which is organic human, animal, and plant wastes, can be safely dumped into water if there is enough oxygen to allow the bacteria which use oxygen ("aerobic") to break down the wastes. If there is not enough oxygen, bacteria which do not use oxygen ("anaerobic") will do some of the waste breakdown. These anaerobic bacteria produce undesireable gases,

slime and general pollution as a result of breaking down organic wastes. Thus even "biodegradable" wastes can pollute water, if dumped in too large quantities.!

Industrial wastes from textile factories, paper mills, slaughter houses, etc., are often released into waterways. Factories dump salts, acids, oils, tars and greases. Tremendous amounts of water are used for cooling purposes; this water when released increases the temperature of the waterway which, as we have seen, lowers the amount of dissolved oxygen.

Agricultural chemicals, including weedkillers, pesticides and fertilizers, are washed from the ground or seep into rivers. In addition to the obvious harmful effects of herbicides and pesticides on aquatic life, the introduction of fertilizers into the water can produce an increased growth of aquatic plants. As plants multiply, they cover large areas of the water and reduce the water's ability to receive oxygen from the air.

Treatments: Much of the harmful materials in human wastes can be removed prior to releasing the wastes into waterways. **Primary** treatment removes the heavy, solid waste material by passing wastewater through a coarse screen, and then allowing heavy matter to sink out in sedimentation tanks. After primary treatment, wastewater contains only dissolved materials and very tiny particles and organisms. Primary treatment reduces waste content by 35-40%.

Secondary treatment, using either a filter of crushed stone (trickling filter method) or a combination of aeration and bacterial breakdown (activated sludge method), destroys harmful materials. Primary and secondary treatment combined reduces waste content by 80-90%.

As would be expected, it is much more expensive to use both primary and secondary treatment. In fact, as the reduction of wastes reaches 95% and up, costs escalate sharply.

III. How to Use POLLUTE

POLLUTE focuses on part of the water pollution problem; the accumulation of certain waste materials in waterways and the impact of these wastes on the level of dissolved oxygen in the water. POLLUTE is very easy to use. You will specify the following inputs:

1. Type of body of water (large pond, large lake, slow-moving river, or fast-moving river);
2. Water temperature (in degrees Fahrenheit). A range of 32-70 degrees is reasonable.
3. Type of wastes released into water (industrial or sewage).
4. Rate of dumping of wastes (in parts per million - PPM - per day). The ratio of 1 PPM can be illustrated by these examples: 1 inch = 1 PPM of 16 miles; 1 lb. = 1 PPM of 500 tons; 1¢ = 1 PPM of $10,000. The dumping rate should be kept between 0 and 14 PPM per day. New York City pollutes its water at a rate of 12 PPM per day, so this range is reasonable.
5. Type of waste treatment (none, primary or secondary).

After these variables have been entered, POLLUTE will determine the oxygen and waste content of the water for each simulated day until the system reaches equilibrium; that is, until the oxygen content and the waste content no longer change over time. You can choose to have the computer print out the data in the form of a table, a graph or both.

IV. Suggested Exercises

The exercises below will give you an idea of the kinds of investigations you can undertake using POLLUTE. They are also suggested as exercises that can be done by students in the classroom.

A. Type of Receiving Body: Suppose Wilkins Toy Company has the choice of locating a new plant on the shores of a large pond, a large lake, a slow-moving river, or a fast-moving river. The company will be dumping untreated waste into the waterway at a rate of 8 PPM per day. Let's say the temperature of the water is 54°F. Use POLLUTE to investigate the ecological effects of location at: 1. a large pond, 2. a large lake, 3. a slow-moving river, and 4. a fast-moving river. Consider these questions: 1. At what location would least harm be done? Why? Where would the most harm be done? Why? An industry does not always choose a location because it is "best" with respect to ecological considerations. List some other factors which the Wilkins Toy Company would have to consider before deciding to locate in a specific area.

B. Type of Waste Treatment: Suppose the Wilkins Toy Company decided to use primary treatment on its waste. Assuming the company would still dump at the rate of 8 PPM per day and the water temperature would stay at 54°F, use POLLUTE to investigate the effects of their locating at each site. Compare these results with the results you got in A., when the waste was not treated. Discuss the differences.

Use POLLUTE to find out how the effects on the water would be changed at each location if the toy company installed secondary waste treatment devices. Assume all other variables remain unchanged. Compare these results with the results from A. and B. above, and discuss the differences you find.

Secondary waste treatment is almost twice as expensive as primary waste treatment. With this fact in mind, determine the location and the type of treatment you would choose if you were the decision-maker for Wilkins Toy Company. Discuss the reasons for your choice.

C. Effect of Water Temperature on a Large Lake: Suppose the Laronde Nuclear Power Plant is located on a large lake and that it dumps waste at the low rate of 2 PPM per day, using primary treatment on its waste. In addition, assume that it uses large quantities of water for cooling purposes, and when the used water is returned to the waterway, it is hot enough to effect a rise in temperature in the lake in the vicinity of the plant. Assume that the normal temperature of the lake is 45°F. Use POLLUTE to determine the effects of increasing the lake's temperatures to: 45°F (normal temperature); 50°F; 55°F; 60°F; and 65°F.

Assume that the power plant can install cooling devices to lower the temperature of the used water before discharging it, but that the more the water is cooled, the more expensive the process becomes. The determination of how much the used water must be cooled depends on the water temperature to which the lake can rise before ecological harm begins. From the data you just gathered, determine the maximum "safe" water temperature under the same conditions as given above. You may want to use POLLUTE again to get more data for this determination.

D. Effect of Type of Waste: Use POLLUTE to determine the effects of dumping untreated sewage into each of the different types of waterways at a rate of 8 PPM per day. Assume the

temperature of the water to be 54°F in each case. Use POLLUTE to determine the effects of dumping sewage which has had primary treatment into each type of waterway at a rate of 8 PPM per day, with a water temperature of 54°F. Do the same exercise with secondary treatment. Compare the results you got here with those you got in A. and B., in which the Wilkins Toy Company dumped identical amounts of untreated or treated **industrial** waste into waterways at the same temperature. Describe the differences in the effect on each type of receiving body. Can you explain these differences?

E. Effect of Dumping Rate: Suppose the Green Diamond Vegetable Cannery dumps its untreated industrial waste into a fast-moving stream at different rates during the year. Assume the dumping rates for the 6-month period, July to December, were as follows:

July	6 PPM per day
August	6 PPM per day
September	8 PPM per day
October	12 PPM per day
November	10 PPM per day
December	7 PPM per day

Use POLLUTE to determine the differences in the effects of wastes from the cannery on the waterway during each month. Assume the temperature of the water to be 49°F.

How would the effects change if the cannery used primary waste treatment during its peak production months, October and November? Use POLLUTE to help you determine the results.

F. More Problems: Suppose the city of Banfield is located on a slow-moving river and that the city is interested in developing several acres of land on the river. Assume a book-printing firm, Kaplan Publications, would like to purchase the land and establish a plant there. They would dump waste into the stream at 10 PPM per day, but have agreed to install secondary treatment devices. Assume the city has also considered building a sewage treatment plant on the same site. This plant would dump waste at a rate of 6 PPM per day but would only use primary treatment. If the water temperature is 51°F, would it be ecologically "better" to build the sewage plant or sell to the book-printing firm?

Assume an industrial plant is to locate on the shores of a large lake, in which the water temperature is 47°F. Suppose the plant dumps waste at a rate of 10 PPM per day. Would it be a more effective pollution control strategy to require the plant to reduce its dumping rate to 8 PPM per day or to require it to install primary waste treatment? Use POLLUTE to help you answer this question. Then use POLLUTE to determine a set of "equivalent" alternatives for the firm. That is, determine what would have the same effect as the installation of primary waste treatment. What dumping rate would have the same effect as the installation of secondary treatment devices? Discuss the pollution control alternatives from an economic point of view. Include several appropriate questions which would have to be answered prior to any decision.

V. Plan for Using POLLUTE in the Classroom

As described in the Introduction, POLLUTE encourages active involvement of the user to investigating the problems of water pollution and how to manage them. When POLLUTE is used in the classroom, such a degree of student involvement contrasts with what is often available and can significantly enhance the students' interest and learning. In addition, the student is able to experience science as an active process of inquiry and can begin to develop skills useful for active problem investigation.

POLLUTE can be used by individuals, teams of students, or entire classes (with appropriate viewing equipment). Investigations may concentrate on: 1. the relative ability of each type of receiving body of water to handle waste; 2. the effects of thermal pollution (by varying temperature); 3. the effects of seasonal variations in the water temperature; 4. the relative effectiveness of no waste treatment, primary treatment and secondary treatment; 5. the effects of a variation in dumping rate; and 6. the relative effects of industrial waste and sewage. POLLUTE may be used as a laboratory experiment: e.g., data is gathered, analyses are made, reports are turned in and discussion follows.

Before POLLUTE is used, students should clearly understand:

1. How water acts on waste;
2. The importance of the water's oxygen level for waste breakdown and for the fish that inhabit the water;
3. The types of human waste: industrial and sewage;
4. The difference between biodegradable and non-biodegradable wastes;
5. the processes involved in primary and secondary treatment; and,
6. The effects of temperature on the physical properties of water and oxygen.

Additional material on these issues can be found in the POLLUTE Resource Manual available from Digital Equipment Corporation.

Students should understand the terms and units used in the program. Students should also realize that POLLUTE is a simulation and should review the assumptions underlying the program. The teacher should explain the program and how to use it.

The following discussion questions may be used in addition to those generated by the students and teacher:

1. What is the effect of each of the input variables on the oxygen content of the water? Are there any trade-offs among the variables? E.g., how much can the dumping rate be increased if secondary treatment is used? How is the dumping rate curtailed if the water temperature is high?
2. How would you go about setting standards of water quality? What variables must be considered? Whose interests are involved? What value judgments must be made?
3. Suppose an industrial firm is considering establishing a plant on the shore of a river and that the firm produces a non-degradable waste which, when untreated, is poisonous to fish. Suppose also that a commercial fishing company is operating downstream from the firm's proposed site and that it offers to pay the industrial firm either not to locate on the river or to treat their wastes so they will not be toxic to the fish. What considerations should be made by both firms? E.g., how much should the fishery be willing to pay? Should it even have to pay? How much should the industry be willing to accept? What "rights" does each firm have? What legal questions are involved? Would the purpose of the firm make any difference?

(e.g., a medicine production firm vs. one which makes dyes for paper).

4. Do you think that industry should be **required** to control its pollution? Should taxpayers be required to pay any of the cost of pollution control for private industry? Would taxpayers be indirectly taxed if the government were to give tax incentives to business to control their pollution?

POLLUTE Model Assumptions

1. The rate of generation of natural wastes and human wastes is constant throughout the year. Only natural wastes exist in the body of water prior to the first day on which human pollutants are dumped into the water. There is no interaction between natural and human waste. Natural waste decomposes at the same rate as sewage.
2. Phosphates, nitrogen, dissolved gases, suspended wastes are not important (or, at least, not of interest and not coupled to our variables).
3. The rate of waste decomposition is not dependent on water temperature and is independent of the oxygen level in the water. As the oxygen level falls, anaerobic organisms begin to take over waste decomposition and maintain the same rate of breakdown.
4. There are no differences in industrial pollutants (e.g., no difference is acknowledged between the wastes from a vegetable cannery and those from a chemical plant).
5. There are no seasonal variations in the water body.
6. Game fish (perch, trout, etc.) die or leave the area when the oxygen level drops below 5 PPM.

RATS: Rat Control Population Simulation

I. INTRODUCTION

A public health commercial on a metropolitan TV station shows a young child playing in a crib in a run-down apartment. A rat scurries across the floor. The child calls, "Here kitty, kitty, kitty."

The child's mistake horrifies the viewer, and one cannot help but take a minute out of their TV watching to think about the necessity of rat control. Because rats carry disease and thrive on garbage, good sanitation is a must in populated urban areas. But if garbage is uncollected, rats can multiply. When the conditions grow serious, health departments may take steps to clean up an area and use the technology they have available to eliminate rats.

In RATS you play the role of a health department official devising an effective, practical plan to eliminate a rat problem. You will develop a plan to control rats in your area of responsibility and will vary the plan to determine the most effective strategy for controlling the rat population. You will select:

1. Whether you want the simulation to take place in a city or an apartment building.
2. The garbage level in your area. The number of rats that can exist in your area depend on the garbage level. If there is a large amount of food with many nesting sites for rats, then the garbage level would be 10, indicating the worst sanitation possible. A garbage level of zero indicates the best sanitation possible. The maximum number of rats that can be supported in a city when garbage levels are at their worst, is 1 million. This maximum number is called the city's "carrying capacity." The apartment house, which has 4 stories and a basement, with 4 apartments on each floor, can support a maximum of 200 rats: 8 to each apartment, 8 to each hallway, and 40 in the basement.
3. The initial population (you may also ask RATS to initialize the population for you).
4. The date for each summary report. It is a good idea to try a control plan for a short period of time (e.g., a few weeks), then get a report to see how well your plan is working. At each report date, you can continue your plan beyond that day, revise your plan and then continue, start over, or quit the program entirely.
5. The type (none, quick-kill, or slow-kill) and quantity of poison you want to use in your control plan. At each report date, if you decide to continue beyond that date, you may leave the old poison out, pick it up and add new poison, or remove the old poison entirely.

RATS will print out daily rat population reports or only monthly reports, as requested. If daily reports are requested, graphic and/or table formats may be requested. Summary reports also show the distribution of

the rat population by age (in months), the number of births and deaths, and the amount of immigration (rats entering the area) and emigration (excess rats leaving the area). When you decide to stop a control plan, RATS will list the accumulated births, deaths, emigration and immigration; the damage (in $) done by the rats; the contamination level produced by the rats; the type and amount of poison uneaten; and the cost of the program.

II. HOW TO RUN RATS

RATS asks you for the input items described above. You will first decide whether to develop a control plan for a city or an apartment house. Next the rat population is initialized:

DO YOU WANT TO INITIALIZE THE RAT POPULATION (TYPE '1') OR DO YOU WANT ME TO DO IT (TYPE '2')?

If you initialize the rat population yourself, RAT asks "HOW MANY RATS ARE PRESENT?" You may not initialize the rat population to a value greater than the maximum population for your area (see description above).

If you asked RATS to initialize the rat population, RATS will do so based on the garbage level you select.

Next RATS asks:

DO YOU WANT A DAILY POPULATION REPORT (TYPE '1') OR ONLY A MONTHLY REPORT (TYPE '2')?

If you select a daily report, RATS asks "DO YOU WANT A TABLE, GRAPH OR BOTH? Choose the format you prefer.

RATS next asks you to "ENTER MONTH, DAY FOR REPORT." The date is always entered as month first, then a comma, then the day. Each month is assumed to have 30 days. The numbering of the months always begins at 1 from the start of the program. Thus, if you wanted your first report after 2 months, you would enter "2,30" in response to "ENTER MONTH, DAY FOR REPORT." As noted above, you may enter new environmental conditions after the report date, revise your control plan if desired and then continue from that date.

RATS next asks "TYPE OF POISON (0-NONE, 1-QUICK-KILL, 2-SLOW-KILL)." "Quick-kill" poison immediately kills any rat that eats it. This poison's efficiency drops to zero after the first kill because the remaining rats refuse to eat any when they see the corpse by the poison. If not used again for 6 months, its efficiency increases 10% per month until it returns to its peak 60% efficiency.

"Slow-kill" poison will eliminate all the rats if no other food is available. It takes 3 to 10 consecutive feedings (the exact number is selected randomly in RATS) before death occurs. A rat will eat slow-kill poison more than once because there is no evidence that it is poisonous. Rats eat only once a day. The older the rat, the more poison needed to cause death. Also the number of rats that eat a poison depends on the ratio of non-poisonous to poisonous food available.

III. SUGGESTED EXERCISES

A. Population Growth Rate

1. Run RATS specifying the environment as an apartment house. Start with 35 rats, get a daily printout until the 15th day of the 1st month. Specify a garbage level of 8 and do not use any poison. Then continue the run until the 30th day of the first month, with a daily printout, a garbage level of 8 and no poison. Does the growth rate of the rat population for this first month seem to be uniform? Do you think the population would continue to grow for another month until it reached 300 to 400 rats? What factors that are reported in RATS seem to cause the population growth to increase? Decrease?

2. Run RATS again for an apartment building. Start with 35 rats, get a report on the 30th day of the first month. Specify the garbage level at 8 and do not use any poison. Continue the run with a daily printout until the 15th day of the second month. Keep the garbage level at 8 and use no poison. Then continue until the 30th day of the second month with the same conditions. Compare the results you got on 1/30 here with those you obtained at the end of the first month in Part 1. Was the total population about the same? Did any of the births, deaths, immigration or emigration vary between the two runs by the end of the first month? What happened to the population growth rate during the second month? Looking at the overall population growth and the detailed factors (births, deaths, etc.), what would you conclude happens when the population becomes greater than an area can support?

3. Run RATS for a city starting with 100,000 rats. Specify a daily printout and a summary report every 30 days for two months. Maintain a garbage level of 8 and use no poison. Graph the population growth for the first month. What then happens to be the population growth during the second month? Would you expect the growth rate to continue during the third month as it did during the second month or would you expect it to be more like the first month? Why?

B. Quick-kill Poison

Often when a person wants to rid an area of rats, she/he thinks of poison which will do the job quickly. A quick-kill poison is the obvious solution.

1. How effective is quick-kill poison? Use a quick-kill poison for 5 days in a city with a garbage level of 1. Start with 50000 rats, using 1 lb. of poison per rat (3 oz. per day). Get a daily report. Continue the run for another 5 days, leaving the current amount of poison in the area and keeping the garbage level at 1. Calculate the death rate for each period by dividing the number of rats at the beginning of each 5-day period **into** the number of deaths during that period. E.g., if you started with 50,000 rats and 30,000 were killed, the death rate would be: (30,000 ÷ 50,000 =) 0.6. Compare the death rate for the first 5 days with the death rate for the second 5 days. What conclusions can you draw from the difference?

2. What if fresh poison were put out every day? Make a new run using quick-kill poison in a city with a garbage level of 1, starting with 50,000 rats. Use 1 lb. of poison per rat for 1 day. Then continue the run for a 2nd, 3rd, 4th and 5th day, getting a report each day. Keep the garbage level at 1 and administer an **additional** 50,000 lbs. of fresh poison each day (the old, uneaten poison in the area will continue to be present). Calculate the death rate for each day (number of rats that died that day divided by the total number of rats originally present that day). Why are some rats dying even though the poison is not eaten? Compare the results here with those of Part 1. Which method achieves the best kill rate? Which would probably cost the least?

3. How much quick-kill poison is needed to be effective without costing too much? Run RATS for 1 day for a city with a garbage level of 1, initial rat population of 50,000, and with the following "ladder" of quick-kill poison levels: 75,000, 50,000, 25,000, 15,000, 10,000, 5,000 and 2,500 lbs. Compare the number of

rats killed and amount of unused poison for each of these poison levels. Your results should show that the optimum amount of poison is around 15,000-25,000 lbs. Try this same investigation for a city with a garbage level of 5 and an initial rat population of 250,000 rats.

C. Slow-kill Poison

This poison is so named because repeated feedings are needed to cause death. Death may occur from 3 to 10 days after the poison is spread. In addition, as the rats get older, more feedings are needed. RATS simulates real life by randomly selecting the first day on which death is to occur. Thus every run is different; however, the amount of poison needed can be figured approximately for any run.

Rats feed once daily and need at least 3 oz. of food per day. Thus in 5 days each rat eats about 1 lb. of food.

Kill-rate curves can be developed which will allow you to predict with some accuracy the population remaining alive on any day and the best day for spreading more poison.

Run RATS for 30 days for a city with a garbage level of 1, initial rat population of 50,000 and using slow-kill poison at a rate of 1 lb./rat for every 5 days. For the first 30 days this would require 300,000 lbs. of poison (6 x 50,000).

Rerun RATS several more times with the same garbage level and initial rat population. Each time run for 30 days. Use these amounts of slow-kill poison: 250,000, 500,000, 1,000,000 and 50,000 lbs. For each run, plot the number of rats alive on each day against the number of days. From any one of these curves, can you determine the day on which the population can be expected to reach its low point? Why, with even 1,000,000 lbs. of bait, do you not eliminate the rats? Is simply placing out more and more poison the best answer to rodent control? Examine your last run using 50,000 lbs. of poison. What happens to the rat population during the first few days and the last two weeks of the month when all the poison is gone?

D. Reducing Garbage in a Rat-infested Area

An area's carrying capacity depends on its garbage level. Cleaning up the area reduces the carrying capacity. What becomes of the rats when the carrying capacity is reduced?

Make **one** run using a "ladder" of garbage level values. Run each level for 15 days with a daily report, for a city where the computer specifies the initial rat population, and using no poison. Start with a garbage level of 10. After 15 days, reduce the garbage level to 8; then after each 15-day period, reduce the garbage level by 2. When a garbage level of zero is reached, keep repeating the run at this level every 15 days until a zero population is reached.

At the end of the first run of 15 days and at a garbage level of 10, add the number of rats that were born to the initial number of rats. How does this compare with the number reported on day 15? How do you account for the difference? Does the same result hold true for all other garbage levels? About how many days at a new garbage level were necessary to reach an equilibrium state? How many days at a garbage level of 0 were needed to reduce the rat population to zero?

E. Combining the Variables

Using the information you have developed on quick-kill poison, slow-kill poison, and reduction of the garbage level, write a plan for cleaning up a city with a garbage level of 10. Remember that clean-up of garbage in an area takes considerable time. (You might do some investigation to figure out how long it does take to clean up an area.) When you have completed your plan, try it out with RATS. If problems develop, modify your plan and run it again using RATS. Try to get rid of the rodents in the least possible time without any of them emigrating from the area.

IV. PLAN FOR USING RATS IN THE CLASSROOM

The exercises suggested above provide a focus for investigating rat control in the classroom. Teams of students can be assigned to make each of the basic investigations in the suggested exercises and to draft and test a plan for eradicating the rats. The results obtained by the teams could be compiled and compared to determine the most effective approach and some alternative approaches which might need to be considered in a real-life test.

Upon completion of this unit on rat control, students should be able to:

1. Describe the effect of slow-kill and quick-kill poisons on a rat population including the degree of effectiveness, time-lag before death, quantities needed for total effectiveness and proper sequencing for deployment of each;
2. Describe the effect of the garbage level on the rats including what occurs when the population is above or below the carrying capacity;
3. Describe the relationship between the rat population, contamination level and damage in dollars;
4. Describe the most effective means for rat elimination or control; and,
5. List the reasons for multiple runs and multiple sampling when performing experiments.

To help students achieve these goals, some follow-up questions and answers are given below.

1. Why does the number of rats in an area exceed the maximum carrying capacity? Because offspring keep showing up.

2. What happens to the excess rodents? They die or leave the area within a very short time.

3. What factors limit a rat population? The amount of water, food, and harborage.

4. If an existing rat population is less than an area can support, what happens? The void is quickly filled with newborn and immigrating rats.

5. What factors determine how fast a rat population increases? Sanitation level, age of present rats and immigration rate.

6. How realistic is it to have a sanitation level of zero? Almost impossible.

7. a) What happens if you have a high rat population, drop the sanitation level and fail to use a rodenticide? Many of the rats emigrate out of the immediate area.

b) Why is this dangerous? It spreads rats to other areas and makes eventual control more difficult.

8. How does the sanitation level affect an area's carrying capacity? The worse the sanitation, the more rats you have.

9. Is rodent control using only rodenticides effective? Why? No. You must clean up to avoid an increase of new rats.

10. What problems are created by large numbers of rats? Rats carry diseases and parasites to humans. They also damage property by chewing and contaminate food by leaving hairs and fecal droppings.

11. Is continued rat control necessary? Why? Yes. New rats migrate into the area.

12. Why was the poison less effective when there was more garbage around? The rats eat the garbage instead of the poison.

13. Why would you want to get a detailed report of the rat population before proceeding with your control program? It helps determine how many offspring to expect within the next 30 days.

14. What is the best plan for eliminating the rats? The best plan calls for: a) putting out a quick-kill poison for 1 day (3 oz. of bait per rat); and b) cleaning up the area and, at the same time, putting out enough slow-kill poison so that there is at least 1 lb. per rat. Continue to put bait out for as long as you run the program, especially if the garbage level is greater than zero. The idea is to eliminate the rats without having them migrate out into the surrounding area.

MALARIA: Malaria Eradication Program

I. Introduction

Health is a biological and medical concern. Or is it? Most young Americans enjoy good health, and we sometimes forget that much of the world still lives under a constant fear of disease and death. When many people in a society are threatened with serious illness or death, this affects not just the health of the individuals, it can also affect the economy, the political system and the general morale. If many people in a country are ill, they cannot work. Productivity falls, the country's economy suffers and this in turn lowers nutrition, reduces health services and increases the chance of disease. The lowered vitality of a nation's people, resulting from widespread illness, impedes the evolution and implementation of social reforms. Even political stability can be affected by health since a society of ill people lacks the stamina to withstand internal and external political threats. You can see then how many underdeveloped countries, as well as some areas in well-developed countries, can get caught in a downward economic, political and social spiral.

Malaria is a classic example of a world health problem that has caused many deaths and has brought on severe economic and social problems in many parts of the world. With MALARIA, you can try your hand at playing the role of a health official trying to control a malaria epidemic while simultaneously taking into account financial considerations. When you use MALARIA with a budget, you will experience the difficulties that often accompany attempts to balance health and economic concerns.

II. Background

Malaria is a disease caused by some one-celled animals called protozoans. These protozoans infect human blood cells, develop into male and female cells, and then become dormant. If a female of a certain species of mosquito called ANOPHELES bites the human at the right time, the mosquito will suck up some of the protozoans. The male and female protozoans mate in the mosquito and release tiny bodies called sporozoites into the mosquito's mouth. If the mosquito bites another human, it injects some of the sporozoites, which enter the human's red blood cells to burst, triggering the symptons of malaria. The chain of infection, then, goes from man to mosquito to man.

Malaria can spread at alarming rates. One person could infect 800 mosquitoes who could then distribute up to 1120 infections! These numbers are upper limits; the actual number might well be lower. Still, you can see how rapidly the infection can spread.

Where is malaria most often found? Since mosquitoes carry the disease, and since mosquitoes require warm, stagnant water for their larvae to develop, malaria tends to be found in warm, moist climates with lots of standing water. Many areas of Central and South America, Central and South Africa, and Southern Asia are troubled with malaria.

How can malaria be controlled? Quinine and some more recently developed synthetic drugs are good for combatting the disease once it has struck. Immunizing drugs are also available to help prevent people from contracting the disease. Another extremely important way of preventing malaria is to destroy the mosquito population. Since 1962, the pesticide DDT has been used widely for this purpose and has freed more than a billion people from the threat of malaria. While DDT is highly effective against malaria-bearing mosquitoes and is relatively inexpensive, it has come under attack for its negative impacts on the environment, including killing non-pest species. More environmentally sound pesticides such as malathion have been developed to be used against malaria-bearing mosquitoes, but these tend to be far more expensive than DDT and often are beyond the budget of malaria-infested countries, which tend to be poor. Biological control methods, such as releasing sterile male mosquitoes and importing mosquito-eating minnows, have been tried but so far without spectacular success. Because pesticides are still the most widely used method of eliminating mosquitoes, they are the only means for destroying mosquitoes that you will have available in MALARIA.

III. How to Run MALARIA

MALARIA is very easy to run. Your starting conditions are as follows. You will try to control a raging malaria epidemic in an area with a total population of about 100,000. Approximately 25000 are ill with malaria and 1000 people died in year 0, which is the year prior to the beginning of your control effort. Your goal is to reduce the number ill from malaria to below 1000 for 5 consecutive years.

You have four methods available for controlling the epidemic:

1. field hospitals of 20 beds each. These isolate the ill and facilitate treatment. Each hospital costs $2000/year.
2. drugs for the ill — these cost $2/year/person.
3. pesticides for mosquitoes. You have a choice of DDT, malathion or propoxur. DDT is cheaper but less environmentally desirable. Costs for a full anti-mosquito spray (designed to destroy 100% of the mosquito population in that year, although the actual effectiveness will be lower than 100%) are $75,000/year for DDT, $231,000/year for malathion and $637,500/year for propoxur.
4. preventative drugs — these cost 72¢/person/year.

MALARIA asks you when and how much of each control method you wish to use. You will input for each of 5 years the number of hospitals, number of doses of preventive and curative drugs, and the percentage of mosquitoes flying around that year you want to eliminate. MALARIA then evaluates the success of your program. You may then continue from the 5th year, start over, or stop completely. When studying your results, remember that year 0 is the year prior to the start of your control effort.

You may use MALARIA with or without a budget. If you use MALARIA with a budget, you will have $500,000 maximum to spend over 5 years. MALARIA will not let you exceed your budget; you will be informed if you've gone over your limit and asked to re-input the last control method requested. We suggest you try MALARIA without a budget first to get a feel for the cost and effectiveness of each method.

IV. Suggested Exercises

There are many ways you can try to control malaria using MALARIA. Here are some suggested problems for you to focus your efforts on:

1. Can the epidemic be eradicated by using only one option for all 5 years? Try to explain your results.
2. Which of the 4 treatment methods was the most effective when used alone in reducing both the number of sick and the number of dead? Which was least effective? Can you think of some reasons for your results?

Curative activities are directed at the cure of malaria victims. **Preventive** activities are intended to prevent those who are still healthy from getting malaria. Hospitals and drugs for the ill are curative measures; mosquito control and preventive drugs are preventive measures. Use MALARIA with no budget to help you answer these questions:

3. Can the malaria epidemic be successfully eradicated using only curative measures, that is, using only hospitals and drugs for the ill? Why or why not?
4. Can the epidemic be eradicated using only preventive measures, that is, just using mosquito control and immunization program? Why or why not?
5. Compare the results you got in (1) with those you got in (3) and (4). Was the combined use of a mosquito-control plan and an immunization plan more effective than the use of either plan alone? Was the combined use of hospital beds and drugs for the ill more effective than the use of either alone? Why or why not?
6. Using the information you got from the previous exercises, try to devise an eradication strategy. Do not use a budget restriction; simply try to wipe out the epidemic in 5 years. Spend as much money as you need. Recording your strategy on a PLAN OF ACTION sheet like the one at the end of this section will help you organize your computer time more efficiently. If your first strategy doesn't work, try others until you find an effective one.

Exploration Exercises: Costs

The previous exercises were not concerned with costs. Cost, however, is a very real factor in any health maintenance effort. In the following exercises, you will consider this financial dimension.

1. Use MALARIA without a budget restriction to determine which of the 4 treatment methods is cheapest when applied to the maximum degree you would (or can) use in the epidemic area described by MALARIA. Which one is most expensive? Which option was most effective? Least effective? Is there any relationship between the cost and the effectiveness?
2. Keeping in mind the costs you found in the last exercise, devise a control strategy to use with a budget restriction of $500,000. If your first strategy doesn't work, try others until you find an effective one. Record your strategy and its results on a PLAN OF ACTION sheet.
3. How did the best malaria eradication strategy you found for working with a budget differ

from the best one you found for working without a budget?

4. If the most effective plan you found in (2) used a mosquito-control measure, run the program using exactly the same plan but without the mosquito-control measure. How do the costs compare? How do the results compare?
5. Run MALARIA again using the best plan you found in (2) but this time eliminate the preventive-drug program instead of the mosquito-control measures. How do the costs compare? How do the results compare?
6. Ecologically speaking, DDT is an undesirable pesticide; however, the other two pesticides offered by MALARIA are more expensive. A full treatment with malathion would cost about 3 times as much as a full treatment with DDT; a full treatment with propoxur would cost 8 1/2 times as much. Use MALARIA to find out if the use of alternative pesticides affects the flexibility of your control program, given a limited budget.
7. What frustrations, if any, did you experience in working with a budget limitation? Do you think your problems were realistic?

Exploration Exercises: Complications

Budgetary restrictions are only one of many ways in which real-world constraints might limit your ability to carry out a planned malaria control program. The exercises below add another dimension to your problem-solving by adding different conditions to the game.

1. You are directing a 10-year malaria control program. You have $500,000 to spend for the first 5 years and are supposed to have $500,000 for the next 5 years. But during years 6 and 7, a severe economic depression cuts all your funds off. You can do nothing at all during those 2 years and your funds for years 8-10 are reduced to $300,000. Try to eradicate the epidemic with MALARIA and these conditions.
2. You have $500,000 to use over a 5-year period. Just before your third year, the United Nations bans DDT for 2 years pending a study of its impacts. This means you cannot use DDT during years 3 and 4 and are unable to order alternative pesticides due to time considerations. In year 5 the ban is lifted to the extent that DDT can be used in emergency health programs. So you can use DDT in year 5. Use MALARIA with these conditions.
3. You are directing an eradication program with a $500,000 budget for 5 years. After 3 years, a war breaks out and you cannot get any curative or preventive drugs for a whole year. Your supply is resumed in year 5. Use MALARIA with these conditions.

PLAN OF ACTION CHART

Treatment Method	Cost Per Unit	No. Units or % Efficiency	Total Years In Effect	Total Cost
Hospitals	$2000	X____hospitals/year	X____years	=$_____
Drugs for Ill	$ 2	X____doses/year	X____years	=$_____
Mosquitoes	In 1000's			
Pesticide:				
a. DDT	$ 750			
b. Malathion	$2310	X____% killed	X____years	=$_____
c. Propoxur	$6375			
Preventive Drugs	$ 0.72	X____doses/year	X____years	=$_____

(Amount allowed = $500,000 if using budget) Grand Total = $_____

V. Plan for Using MALARIA in the Classroom

MALARIA can be used to serve these educational objectives: 1. conveying to students the complexity of health problems which concern not only health and biology but also economics and ecology; 2. to expose students to the areas of public health and epidemiology; 3. to help students gain a sense of the various strategies for fighting an epidemic and their relative costs and effectiveness; and 4. to allow students to explore the consequences of banning DDT to world malaria control efforts.

After working with MALARIA, students should be able to 1. briefly discuss the disease of malaria: how it is transmitted, the conditions under which it will appear, strategies for eradicating it, and its current world status; 2. discuss the effect of field hospitals, drugs for the ill, mosquito control using pesticides, and preventive drugs, on a malaria epidemic; 3. discuss the most effective strategy found for controlling malaria with and without a budget; 4. summarize the major arguments for and against the use of DDT; and 5. discuss some political, social, economic and ecological concerns related to health.

MALARIA can be used in biology, social studies and health classes when health issues are being discussed. MALARIA is also a good introduction to modeling and simulation.

Prior to using MALARIA, students should acquire some background information on health, epidemic control, malaria and pesticides. The MALARIA Resource Manual, available from Digital Equipment Corporation, provides material and references sufficient for this purpose. Students should also understand they will be using a model that is based on certain assumptions and should know how to use MALARIA. Students can use MALARIA individually or in groups. The suggested exercises above can provide some thought-provoking questions to stimulate students' investigation of MALARIA.

You may want to spend one or two class periods discussing the results. In addition to discussing questions related to the objectives stated above, the following questions may also provoke discussion:

1. Even when control strategies are used in full strength, their actual effectiveness was always less than 100%. Can you think of some reasons why this would be so for each of the four control methods?
2. What are some economic, political, social and ecological concerns involved in solving world health problems?
3. Do you think the results of the simulation were realistic?
4. Who do you think should assume the cost of eradicating malaria or any other epidemic disease on a worldwide basis? Who should decide whether a control program should be implemented in a country?
5. If your control program becomes restricted financially so that you have only enough preventive drugs for half the population, how would you decide who would get the drug?
6. What happens if you cut back on precautionary measures before the epidemic is completely quelled?

MALARIA Model Assumptions

1. The area under treatment has been subject to malaria for a long time and a fraction of the population is assumed to have developed some resistance.
2. In any one year about 4% of those ill will die, if they are not treated.
3. The hospital confinement period for a malaria victim is about 1 year when there are no drugs for the ill and about 7 days when there are sufficient drugs.
4. Drugs for the ill will be used first in the hospitals, if they exist. The surplus will be used on non-hospital victims.
5. Treatment is limited to this one area; surrounding areas are not being treated.
6. The birthrate in the area is high enough that, despite deaths due to malaria, the population remains at about 100,000 throughout the years.
7. Costs used in the program are based on data from the World Health Organization and include administration and personnel costs.
8. The actual effectiveness of any treatment cannot be 100%. For example, a full mosquito spray will not eliminate all the mosquitoes because some are resistant to insecticides; humans make errors in spraying; etc.
9. If drugs are not used in the year ordered, there is a 25% loss per year due to pilferage, chemical breakdown, etc.

DIET: Evaluation Of Diet For Calorie, Protein, Fat and Carbohydrate Levels

I. Introduction

Americans have recently awakened to the fact that although we are the richest nation today, too many of us do not follow diets that provide us with the proper balance of nutrients. Our diet often contains too many snacks and fast foods which provide lots of calories but not enough of the other required nutrients. Only lately has there been a move to re-orient the American diet to one with less fats, fewer calories and more vitamins, minerals, roughage, etc.

DIET is a computer program designed to let you explore the quality of a diet for four basic substances: calories, protein, lipids, and carbohydrates. There are, of course, other important required nutrients such as minerals, vitamins, and water, but DIET only evaluates a diet for the four items above. You give DIET a list of foods, and the amount of each food, eaten in a typical day, along with your age, sex, weight, height and activity rating (a rough measure of how much physical activity you indulge in each day). DIET then analyzes the foods eaten and gives you the total calories consumed for the day as well as the amounts of protein, lipid and carbohydrate provided in your diet. DIET will also compare your diet to the **average** requirements for a person with the same characteristics. The word **average** is very important because no one is truly average, so a small difference from average is probably not important. If you see a large difference between the amounts recommended and the amounts provided by the food you eat, it might indicate a problem that should be studied further.

It is also important to note that DIET evaluates the diet according to what would be needed to **remain** at your present weight. If you want to know what your diet should be to either raise or lower your weight, input your **desired** weight and DIET will evaluate your diet according to how well it will help you reach and maintain that weight.

II. Background

To use DIET most effectively, you should review a little about each of the factors DIET will help you study.

A. Calories. Calories are a measure of energy. The more calories consumed each day, the more energy is being supplied to the person. Your body needs this energy, not only for activities but for repair and growth as well. For instance, when you are asleep your body uses between 70 and 100 calories each hour.

Technically, a calorie is the amount of energy needed to raise 1 milliliter of water 1 degree Celsius (1.8 degrees Fahrenheit). DIET uses the kilocalorie measure, also called a Calorie (with a capital "C"). A kilocalorie equals 1000 calories.

If you consume too few calories, your body will make up the difference by breaking down, first non-vital and

then (in desperation) vital parts of the body. Dieting induces the body to break down non-vital parts and so reduces weight. When the body is forced to break down important parts such as muscles through prolonged inadequacy of diet, starvation occurs with the person looking like a "skeleton with skin."

If you take in more calories than you need, these calories are stored in body fat for later use. This fat is mostly stored just under the skin; you can estimate the amount of fat in your body by pinching skin between thumb and forefinger — the thicker the skin, the more fat you have stored. Any excess calories consumed will be stored as fat even if they were not originally "fat" in the foods you ate (e.g., if they were carbohydrates).

B. Proteins. Protein is essential to the body. It is, next to water and possibly fat, the most plentiful substance in the body; protein is used to build muscles and many cell structures. Since protein is so important for body-building, children need more protein per day than adults. Protein also makes up enzymes and hormones and, thus, is essential for body maintenance.

Proteins are made up of long, folded chains of about 25 different "amino acids." When we eat protein, our digestive tract breaks the protein down into the amino acids, and the amino acids enter the bloodstream to be used to build up new, "human" proteins. Our body is able to build some amino acids itself; nine amino acids, however, have to be obtained from our food. These nine amino acids are called the "essential amino acids." We must take in these essential amino acids in a certain proportion at one time. If we take in an excess of one amino acid, it is rapidly flushed from the body and lost. This is why not just any food protein will do; we must take in the kinds of amino acids and the proportions of these acids we need. The best quality protein (for human consumption) occurs in egg, milk, and cheese, and also soybeans and meat. Quality protein can also be obtained by combining foods that would not have all the essential amino acids in the right proportions if they were eaten alone. Rice and beans or corn and pinto beans are examples of good protein combinations.

C. Lipids. Lipid is a scientific name for fats and oils, which are very concentrated sources of energy. There is almost twice as much energy in fat than in sugar, gram for gram. This is the reason why people on diets try to stay away from fatty foods. Unfortunately, Americans are eating more and more high-lipid foods. Many of our favorite snack foods are very high in lipids. Ten medium potato chips supply 108 Calories and 7.4 grams of lipid. On the other hand, a cup of raisins supplies 429 Calories but only .8 grams of lipid.

A certain amount of lipid is essential for good health. A diet with no lipid produces metabolic problems; chief among these is a breakdown of the skin. In 1953 the United States set the guideline that 25% of the total Calories eaten each day should come from lipids. We use this guideline in DIET, but many experts feel it could be less.

D. Carbohydrates. Carbohydrates are a main source of energy. Both sugar and starch are examples of carbohydrates. Although they are lower in energy content than lipids, they are less expensive and easier to digest. When carbohydrates are eaten, the digestive tract breaks them down into monosaccharides. The monosaccharides diffuse into the bloodstream for distribution to the cells, which then use them for "fuel" to carry out respiration and convert the chemical bond energy into energy useful to the cell. Nearly all our carbohydrates come from plant sources, the only exception being milk.

III. How to Run DIET

DIET is easy to run. Most of the requests for your input are self-explanatory. You may first enter your name so that DIET doesn't feel quite so impersonal. Next you give DIET your "vital statistics": sex, age, height, and weight. Fractions can be used but must be expressed in decimal form, i.e., 16.5 if you are 16½ years old. DIET does not include diets for people over 90 years of age. Also, the results of DIET may be misleading for those under 12, since children have very different requirements from adults. No heights over 8 ft. are accepted, nor weights over 500 lbs. You alo enter your activity rating. This is a rough measure of how much physical activity you engage in daily. DIET prints the activity scale and what each value represents so that you should be able to provide this input easily.

Next, DIET asks you for your daily diet. You input the foods eaten for breakfast, lunch, supper and snacks. To make it easy for you to input your meals, DIET contains a list of 100 foods typically eaten by Americans. These foods are divided into the following types: 1. proteins (meat, fish, poultry, soy); 2. other main dishes; 3. dairy products; 4. vegetables; 5. bread/cereals; 6. fruits; 7. desserts/snacks; and, 8. non-dairy drinks.

For each regular meal and snack meal, DIET cycles through the following procedure until you have selected all the foods eaten at that meal. First, DIET asks you which of the above food types you want to see. Once you've made your decision, DIET lists the foods available for that food type. To the left of each food is a number; you select a food type by inputting that number. To the right of each food, in parentheses, is the serving size (e.g., "each," "slice," or "cup"). When you have selected a food, DIET asks you to enter the number of servings of that food you ate. Fractional servings (e.g., 1.5 cups) are allowed. DIET keeps asking if you want to select another food from the current list printed until you say no. Then you may select another food type for that meal or go on to the next meal. If you can't find the exact food among the 100 foods listed, use a food item from the lists that seems closest to the one you want.

As you choose your foods for each meal, DIET will print them at the top of the screen so you can keep track of which foods you have selected.

After all the foods for the day have been input, DIET totals and evaluates the diet according to the **average** requirements for a person with your vital characteristics. DIET will not report excess protein because too much protein is not harmful and may even be helpful. But excess calories, lipids or carbohydrates will be reported as they may lead to weight gain. DIET prints the amount of weight you can expect to gain or lose, in the near term, if you keep to the diet represented in the foods you selected. If requested, DIET will print a breakdown of the amount of calories, protein, lipids and carbohydrates consumed at each meal.

IV. Plan for Using DIET in the Classroom

A. Before Using DIET. Students should be familiar with the importance of Calories, protein, lipid and carbohydrate in maintaining a healthy physical state. More detailed information on dietary requirements can be found in the DIET Resource Manual available from Digital Equipment Corporation. Some teachers may want to replace the term "lipid" with the non-technical word "fat."

Students should be able to estimate quantities using the English system: cup, teaspoon, tablespoon, and liquid ounce. These units are used in DIET because most foods are still measured in these terms. A useful classroom aid would be an inexpensive set of kitchen measuring instruments: a set of measuring spoons, cups and a scale. Have students measure out quantities available in the classroom.

Most students will want to examine their own diet. Have them keep a careful record of **everything** they eat over several days, including **quantities** as well as items eaten. Be sure to review DIET's assumptions with them. Since DIET evaluates the diet in terms of an "average" person of similar characteristics, any computer evaluation is open to doubt in a particular instance.

Students should be familiar with how to use the computer. Students should also carefully plan their time at the computer. It has been our experience that, if the planning for DIET is given as a homework assignment, students with the most ability will be ready to use DIET at the beginning of class, while others will need varying amounts of class time to complete their planning. This distributes the demand for the computer. In a double period, students should all be able to get their results if they have had experience with other simulation programs.

B. After Using DIET. Students should be encouraged to find out why some people get a good evaluation from DIET while others do poorly. Some students may volunteer to show their diets and results to the class as examples. Students can investigate the qualities of individual foods by creating a diet with a single food for each meal and then requesting a meal breakdown.

C. DIET Model Assumptions.

1. Basal Metabolic Rate (BMR) is calculated using the DuBois formula, using information on height and weight. This calculation assumes an adult stature: DIET types a warning when a subject younger than 12 is modelled.

2. A mixed diet is being consumed, rather than a single nutrient type, e.g., protein.

3. The subject sleeps 8 hours a day. The activity, described by the activity rating, is carried out over 8 hours each day.

4. Protein Recommended Daily Allowances are based on the 1968 Revision of the Food and Nutrition Board, National Academy of Sciences, National Research Council. Lipid allowance is based on Canadian recommendation that 25% of Calories should be from a lipid source.

5. The fuel value of protein is 4.05 Kcal/gram; the fuel value of lipid is 8.93 Kcal/gram.

6. All Calories, not from a protein or lipid source, are derived from carbohydrate.

Ecology Simulations — 2 contains four programs:

1. **POLLUTE: Water Pollution Simulation**
2. **RATS: Rat Control Simulation**
3. **MALARIA: Malaria Eradication Program**
4. **DIET: Evaluation of Diet for Calorie, Protein, Fat, and Carbohydrate Levels**

These programs were originally developed by the Huntington Computer Project directed by Dr. Ludwig Braun under a grant from the National Science Foundation. They were converted for use on several popular microcomputers and graphical output added by Creative Computing Software. Tape cassettes with instruction booklets are available for $24.95 from Creative Computing. Instruction booklets alone cost $1.00.

The original resource manuals developed by the Huntington Project are available for $1.00 for each program from Digital Equipment Corp., Maynard, MA 01754.

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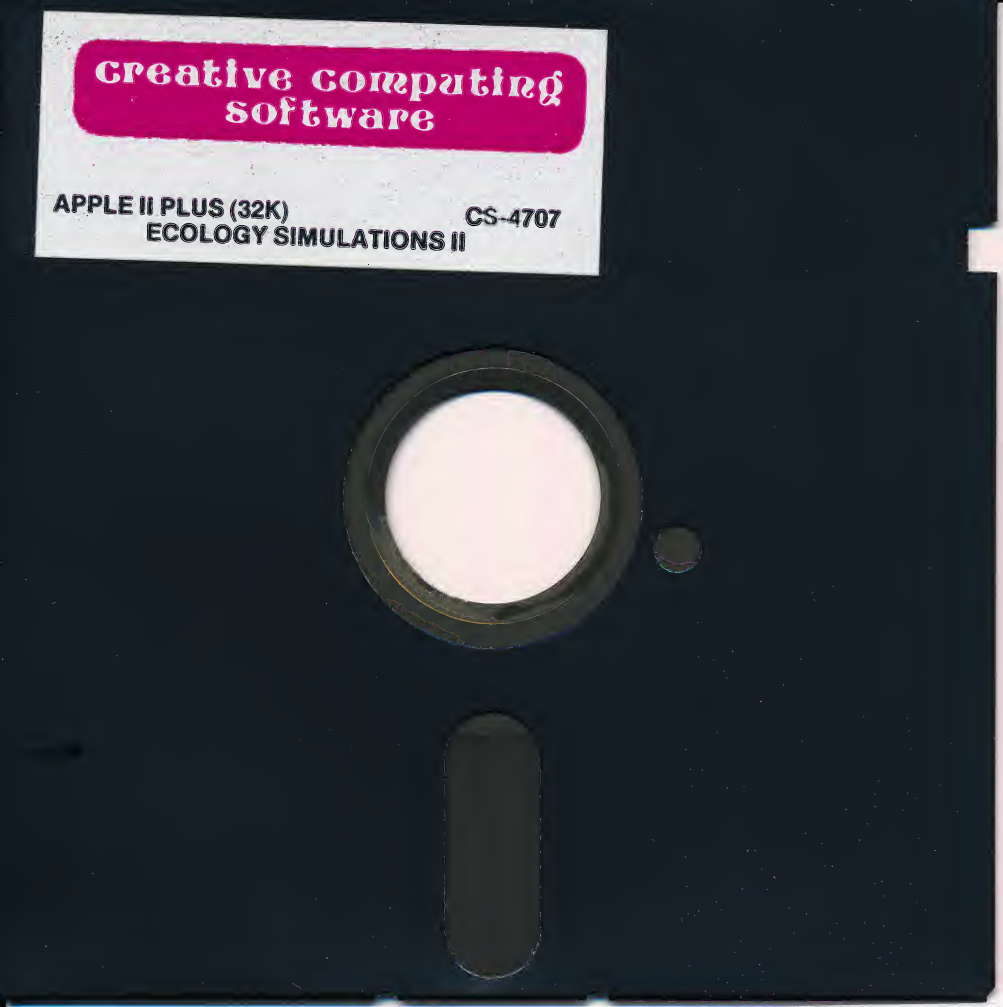

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